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SELECTING MODES FOR PRINTING

BACKGROUND

A printer may create a printed image from print data by placement of
10 colorants in a pattern onto a print medium. The colorants may be placed onto the
print medium in an order determined, for example, by the physical arrangement
of colorant nozzles on an inkjet printhead, and the direction of scan of the
printhead. However, this order may affect the appearance of the printed image.
For example, if the colorants are destined to overlap in a region of a print
15 medium, the order in which such colorants are placed in the region may affect
their hue. Accordingly, a fixed order of placement of colorants may provide
greater color consistency throughout a printed image. However, in some cases a
fixed order of placement may produce a printed image more slowly than an
alternating or more variable order of placing colorants and may not substantially
20 improve some printed images.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a schematic view of print data defining an array of image
elements, with the content of the print data being used to select a mode of
printing a printed image, in accordance with the present teachings.

25 Fig. 2 is a schematic view of a printhead delivering colorants to a print
medium during a successive pair of bi-directional passes over the medium
followed by a set of sequential uni-directional passes over the medium, to create
printed output with lesser and greater printed pixel densities, respectively, in
accordance with the present teachings.

30 Fig. 3 is a view of a system for printing images using modes selected
based on the content of print data, in which a printer of the system is configured
to deliver colorants from a printhead as the printhead moves bi-directionally or

uni-directionally according to the mode selected and thus according to the content of the print data, in accordance with the present teachings.

Fig. 4 is a schematic view of the system of Fig. 3, in accordance with the present teachings.

5 Fig. 5 is a partially schematic view of text printed bi-directionally on a print medium, in accordance with the present teachings.

Fig. 6 is a graph of a content analysis of print data corresponding to the text of Fig. 5, in accordance with the present teachings.

10 Fig. 7 is a partially schematic view of raster-based graphics printed uni-directionally on a print medium, in accordance with the present teachings.

Fig. 8 is a graph of a content analysis of print data corresponding to the raster-based graphics of Fig. 7, in accordance with the present teachings.

15 Fig. 9 is a partially schematic view of printed output including vector-based graphics, text, and a small photograph printed bi-directionally on a print medium and a larger photograph printed uni-directionally on the print medium, in accordance with the present teachings.

Fig. 10 is a graph of a content analysis of print data corresponding to the printed output of Fig. 9, in accordance with the present teachings.

DETAILED DESCRIPTION

20 Methods and apparatus are provided for printing images using printing modes selected according to a content analysis of print data corresponding to the images. The print data may correspond to printed images that are text, graphics, photographs, or portions or combinations thereof, among others. The methods and apparatus may be used to print images bi-directionally or uni-directionally
25 according to the content of the images. Uni-directional or bi-directional printing for each image may be selected according to the percentage of non-white (printed) pixels or white pixels (nonprinted) in the images. For example, some types of raster-based images, such as larger raster-based graphics and larger photographs may be printed uni-directionally. This uni-directional printing may
30 reduce a hue shift visible between adjacent swaths when printed bi-directionally. Vector-based images, such as line-based graphics or text, and some types of raster-based images, such as smaller raster-based graphics and smaller

photographs may be printed during bi-directional movement of a printhead. This bi-directional printing may be suitable for vector-based content and smaller raster-based images to increase printing speed relative to printing unidirectionally. In particular, bi-directional printing may be suitable when a greater hue shift between adjacent swaths, produced by bi-directional relative to unidirectional printing, is not a substantial problem.

Fig. 1 shows print data 20 being used to select a mode 22 of printing a printed image 24 according to the content of the print data. Print data 20 may define a data representation 25 including an array 26 of image elements 28 or pixels. Mode 22 may be selected by analyzing the content of the print data, and particularly by determining an aspect of the defined array. Determining the aspect of the array is described below. The selected mode (or modes) then may be utilized to create printed image 24 on a print medium 30. In particular, the selected mode may define any suitable aspect of how colorant-based representations 32 of the image elements are placed on print medium 30. Accordingly, the aspect may be an order or sequence, a rate, a number of passes (such as a one-pass or a multi-pass mode), and/or a direction of placement of colorant-based representations 32, among others.

Image elements 28 may have any suitable arrangement and properties. The image elements of array 26 may be disposed in a matrix, that is, in rows 32 and columns 34. Each image element may have a defined color. In the present illustration, the image elements are of four different colors 35. In some embodiments, the defined color may have a lightness-darkness value disposed within a range of such possible values, so that the image element is a substantially continuous-tone pixel or contone pixel.

Each image element may have a color characteristic 36. The color characteristic is any generalized or specific aspect of the defined color, such as a category to which the predefined color belongs (such as white or non-white, foreground or background, printed or nonprinted, etc.) or a specific color property. Each image element may have a color characteristic defined by any suitable amount of print data 20. The color characteristic may be defined within any suitable color space, such as red-green-blue (RGB), chromaticity coordinates

(XYZ), cyan-magenta-yellow-black (CMYK), hue-saturation-value (HSV), or the like, and may be defined according to any suitable boundary (or boundaries) or threshold(s) within such color space.

The image elements of the array may belong to two or more different sets 5 38, 40 each having a different color characteristic 36. In the present illustration, first set 38 of the image elements has a non-white color characteristic 36, that is, each member of this set has a defined color that is non-white. Second set 40 of the image elements has a white color characteristic so that each member of this set has white as its defined color. Other exemplary pairs of sets with a different 10 color characteristics may be defined by the presence or absence of a defined color, black or non-black as the defined color, or by any other preselected color criteria as indicated above. In some embodiments, the sets of image elements may be defined according to the color of the print medium, termed the background color. Accordingly, image elements of the array may be foreground 15 elements, with a defined color distinct from the background color, or background elements, with a defined color corresponding to the background color. In the present illustration, the print medium is white, so that first set 38 includes foreground elements for which colorant-based representations 32 are placed on the print medium. Furthermore, second set 40 includes background elements for 20 which representations are produced on printed image 24 without colorant placement at the positions of such representations on the print medium.

First set 38 of non-white image elements is disposed in an arrangement 42 within array 26. Colorant-based representations 32 of the image elements of the first set may be placed on the print medium according to mode 22 and disposed 25 in arrangement 42 defined by the print data.

Each colorant-based representation 32 may be created by one or more colorant pixels 44 on the print medium. The colorant pixels may be halftone pixels, created by placement or non-placement of a particular colorant(s) at different positions within each colorant-based representation. Alternatively, or in 30 addition, the colorant pixels may be contone pixels produced, for example, by dithering and/or by placing different amounts of the colorant(s) at pixel positions of the print medium. Each colorant pixel may be created by one colorant or

through overlap of two or more placed colorants. A colorant, as used herein, may be any visible material applied selectively to, and/or modified selectively on, a print medium. Exemplary colorants may be dyes, such as toners for laser printers or inks for inkjet printers. A print medium, as used herein, may be any medium on which colorants may be placed positionally, including sheet media such as paper, plastic, fabric, metal, etc.

Mode 22 may be selected by a content analysis of the print data, and particularly by determining an aspect(s) of the first set 38 of image elements within array 26. The aspect(s) may relate to the frequency of occurrence of image elements of the first set within the array, and/or within one or more portions of the array, such as in one or more rows or regions of the array. Accordingly, the aspect(s) may be one or more values corresponding to the percentage of image elements of the first set within the array, or within one more portions of the array. This value (or values) may be determined, for example, by calculating the exact percentage of first elements within the array or portions thereof, or by estimating the percentage based on sampling a subset(s) of the array. The value (or values) may be compared to one or more predefined thresholds to select a mode. For example, the thresholds may define a threshold percentage and a threshold number of rows, so that a first mode is selected for portions of the array exceeding the threshold percentage for the threshold number of rows, and a second mode selected for the remaining portions of the array. Further aspects of content analysis of print data are included below in relation to Figs. 5-10.

Fig. 2 shows a sheet of print medium 60 being processed by different modes 62, 64 of printing. Each mode may be selected according to a content analysis of the corresponding print data. Each mode may be defined according to the direction(s) 66, 68 in which a printhead(s) 70 travels over print medium 60 during successive passes 72 of colorant delivery. Bi-directional mode 62 may be selected to deliver colorant for portions of the print data defining a lesser pixel (or image element) density, indicated at 74. This bi-directional mode may deliver colorant in opposing directions 66, 68 during a pair of successive passes 72. Uni-directional mode 64 may be selected to deliver colorant for portions of the print data defining a greater pixel (or image element) density, indicated at 76. This uni-

directional mode may deliver colorant in the same direction (66 or 68) during two or more successive passes.

Each pass, as used herein, includes colorant delivery to a print medium. Successive delivery passes may deliver colorant in adjacent swaths 78 to at least
5 substantially nonoverlapping regions of the print medium, as illustrated here, to effect single-pass printing. Alternatively, or in addition, the passes may deliver colorant in interlaced swaths and to overlapping regions of the print medium, to effect multiple pass printing.

Fig. 3 shows a system 90 for printing images using modes selected based
10 on the content of print data. System 90 may include a printer 92 configured to print images onto print medium 94. System 90 also may include a computing device 96 in communication with the printer, shown at 98, and configured to send print data in any suitable form to the printer.

Printer 92 may be any printing device configured to deliver one or more
15 colorants positionally to print media. The printer may be an inkjet printer or a laser printer, among others. The printer may include a printhead 100. The printhead may be any structure (or structures) from which colorant(s) is dispensed to print media. In the present illustration, printhead 100 is an assembly of printheads included in colorant cartridges 102. In other embodiments, colorant
20 reservoirs may be disposed in a spaced relation to their printheads, that is, off-axis.

The printhead(s) may be stationary or may move relative to print media. In the present illustration, the printhead(s) is configured to scan bi-directionally, in directions 66, 68, along an x-axis defined by the printer. Each scan may function
25 as a pass for colorant delivery (bi-directional printing), and/or approximately half of the scans may function as passes for colorant delivery (uni-directional printing), among others. Uni-directional printing may be in either direction, for example, left to right or right to left. The direction selected for printing an image uni-directionally may be a predefined direction (such as always left to right), or
30 may be defined according to context, such as the position of the printhead(s) at the outset of uni-directional printing. The printer may be configured to move print

media along a y-axis 104 disposed orthogonally to the scan or x-axis of the printer.

Fig. 4 shows a schematic view of system 90. Computing device 96 may be configured to send print data 110 to printer 92. Computing device may be
5 configured to receive print data, perform a content analysis of the print data and/or select a mode(s) of printing the print data, among others. However, in the present illustration, printer 92 is configured to perform these and other tasks that could be assigned alternatively, or in addition, to computing device 96.

Printer 92 may include a data manipulation portion 112 and a colorant
10 placement portion 114. Data manipulation portion 112 may be configured to receive print data 110 from computing device 96 and process the print data into printing instructions for the colorant placement portion. As part of this processing, data manipulation portion 112 may perform a content analysis of the print data and select one or more modes for printing the print data. Colorant placement
15 portion 114 may be configured to dispense colorant positionally to a print medium using the modes selected by the data manipulation portion. Accordingly the modes may relate to how the colorant placement portion performs its functions.

Data manipulation portion 112 may include a printer processor 116 and printer memory 118. The printer processor may be configured to perform
20 manipulation of data received from the computing device and/or from the printer memory, including logic and/or arithmetic operations, among others. Such data may include the print data and processing instructions for the print data. Printer memory 118 may include content analysis instructions 120 and parsing instructions 122. The content analysis instructions may be configured to
25 determined one or more values from the print data and compare those values with at least one predefined threshold (or threshold value) to select one or more printing modes. Parsing instructions 122 may assign portions of the print data to particular passes performed by colorant placement portion 114. The parsing instructions may include directionality instructions 124 that assign a direction to
30 each of the particular passes.

Colorant placement portion 114 may include a printhead reciprocation mechanism 126, a media advancement mechanism 128, and a printhead(s) 130.

Printhead reciprocation mechanism 126 may scan bi-directionally, as illustrated in Figure 3. Alternatively, or in addition, the printhead reciprocation mechanism may move in any other suitable direction, including orthogonal directions, among others. Media advancement mechanism 128 may move print media along an axis orthogonal to the axis defined by the printhead reciprocation mechanism. In some embodiments, the printhead reciprocation mechanism may perform the function of the media advancement mechanism by moving orthogonally. Alternatively, or in addition, the media advancement mechanism may move the media in orthogonal directions. Printhead(s) 130 may include firing elements 132, such as heater elements or piezoelectric elements. The firing elements may operate to expel colorant droplets from nozzles 134 and onto print media.

Fig. 5 shows printed output 150 including a text image 152 printed bi-directionally on a print medium 154. The text image and its text 156 may be printed within a print region 158 of the medium. The text image may be printed during a plurality of sequential printhead passes over print medium 154, with pairs of successive passes being in opposing directions 66, 68, as indicated at 160.

Fig. 6 shows a graph 170 of a content analysis of print data corresponding to text image 152 of Fig. 5. Graph 170 plots contone pixel count 172 derived from print data corresponding to the text image. In particular, the percentage 174 of non-white contone pixels 176 is plotted versus rows 178 of image elements defined by print data for text image 152. Here, in Figs. 5 and 6, and below in Figs. 7-10, the printed output and its corresponding content analysis graph are aligned horizontally.

Graph 170 also indicates predefined thresholds 180, 182 against which non-white pixel count 172 may be compared. In the present illustration, each threshold should be exceeded by a contiguous portion of pixel count 172 to determine the selection of uni-directional printing. Percentage threshold 180 may define a percentage that should be exceeded by pixel count 172. Row threshold 182 may define a number of rows in which the percentage threshold should be exceeded. In the present illustration, the row threshold is about sixty rows. These rows may be contiguous rows, so that the percentage threshold should be

exceeded in each of the contiguous rows in order to select uni-directional printing. In the present illustration, the pixel count from each of sixty or more contiguous rows would need to exceed the percentage threshold to satisfy both threshold requirements. In some embodiments, the percentage of non-white pixels may be averaged over two or more rows, so that fluctuations of this percentage in particular rows are averaged out. The row threshold may correspond to about the length of a printhead or nozzle array, that is, the width of a swath of colorant that can be delivered by the printhead, as measured parallel to the y-axis described above. In some embodiments, the row threshold may correspond to about one-half, about one and one-half, or about twice this printhead (or nozzle array) length. In some embodiments, the row threshold may be one row rather than a set of rows.

In the present illustration, the percentage of non-white pixels exceeds percentage threshold 180 in a number of rows defining portions of the text. However, the print data for text image 152 defines a substantial percentage of white pixels, seen as white spaces between and within text 156. In particular, no set of contiguous rows, equal or greater in number than row threshold 182, exceeds percentage threshold 180 in each of the rows of the set. Accordingly, bi-directional mode 160 of printing is selected.

Fig. 7 shows printed output 190 with a pair of raster-based images 192, including text 194, printed uni-directionally on a print medium 196. Raster-based images 192 may be printed during a plurality of sequential printhead passes over print medium 196, with each pass being in the same direction 66, as indicated at 198.

Fig. 8 shows a graph 210 of a content analysis of print data corresponding to raster-based images 192 of Fig. 7. Graph 210 plots contone pixel count 212 derived from print data corresponding to the raster-based images 192. In particular, the percentage of non-white contone pixels is plotted versus rows of image elements defined by print data for raster-based images 192, as described above in relation to Fig. 6. Raster-based images 192 may be substantially solid-filled graphics or photographs in appearance. Accordingly, the percentage of non-white pixels in pixel count plots of such images may exceed percentage threshold

180, shown at 214. This threshold percentage may be exceeded in a sufficient number of contiguous or adjacent rows so that row threshold 182 is exceeded, shown at 216. Accordingly, each of raster-based images 192 may be printed in a uni-directional mode. It should be noted the comparison with the thresholds may
5 be restarted where the non-white pixel percentage goes below the threshold, such as in gap 218, so that data for each raster-based image is considered separately to determine the printing mode for this image.

Fig. 9 shows printed output 230 including a mixture of printed images 232 on a print medium 233. Printed images of output 230 may include line-based
10 graphics 234, text 236, and photographs 238, 240. Line-based graphics 234, text 236, and small photograph 238 may be printed in a bi-directional mode, shown at 242. Larger photograph 240 may be printed in a uni-directional mode, shown at 244.

This uni-directional mode can be in any suitable direction, such as from left
15 to right, or from right to left. In particular, a direction for this uni-directional mode may be selected based on the current position of the printhead(s) when the uni-directional printing is initiated. For example, if the last pass of a previous (bi-directional) printing period was from left to right, uni-directional printing from right to left may be selected as the most efficient transition from bi-directional to uni-
20 directional printing.

Fig. 10 shows a graph 250 of a content analysis of print data corresponding to printed images 232 of Fig. 9. Graph 250 plots contone pixel count 252 derived from print data corresponding to the printed images 232. In particular, the percentage of non-white contone pixels is plotted versus rows of
25 image elements defined by print data for printed images 232, as described above in relation to Fig. 6. Print data for line-based graphics 234, text 236, and smaller photograph 238 may not define a sufficient percentage of non-white pixels to exceed each of thresholds 180, 182, thus these images may be printed bi-directionally. By contrast, print data for larger photograph 240 may define a
30 sufficient percentage of non-white pixels to exceed each of thresholds 180, 182. Accordingly, photograph 240 may be printed uni-directionally.

In one exemplary embodiment, the present teachings may be used to switch from one-pass bi-directional printing to one-pass uni-directional printing using page content analysis. One-pass bi-directional printing is a print mode that may increase the performance of inkjet printers. In this mode, inks (colorants) are ejected when the printheads travel from left to right and from right to left. One significant problem of this print mode may be a color hue shift produced between swaths printed by the printheads moving in different directions. This color hue shift may be observed as banding artifacts that degrade print quality. Much effort has been directed to calibrating printers and to control the trickle warming temperature, but this color hue shift problem may remain in some cases.

The present teachings may solve this problem of color hue shift in a different way. The solution may be based on the idea that the color hue shift mainly occurs with large size images, but not text, vector based graphics and small imagerettes. In the office or in a home environment, the majority of pages to be printed contain text, graphics, and small imagerettes, with large size images representing only a small percentage of printed output. Accordingly, if the presence of large size images can be detected, a one-pass uni-directional print mode can be used selectively to print these large size images. This selective use of a uni-directional print mode may maintain the performance of the printer and avoid problems associated with compensating for a bi-directional color hue shift.

One-pass bi-directional printing is a fast print mode that increases considerably the performance of inkjet printers. However, it has a drawback: it may use two different color maps for printing in two different directions to correct for the color hue shift. These two color maps may be very sensitive to variations in internal and external printing conditions. Factors that influence printing results include ink drop weight variation, printer trickle warming temperature, environmental temperature, and humidity, among others. To compensate for the color hue shift produced by various printing conditions, several methods have been developed: color calibration has been utilized to compensate for ink drop weight variation, and trickle warming temperature has been adaptively controlled to avoid the ramp artifact. However, these methods may be complicated to implement, and they may not compensate for the color hue shift efficiently. The

main artifacts produced by one-pass bi-directional printing may be banding artifacts between swaths printed by the printheads moving from left to right and the swaths printed by the printheads moving from right to left. These artifacts may be more visible for raster based images, and almost invisible for text. These
5 banding artifacts may be eliminated by using one-pass uni-directional printing.

A page of printed output may have one or more of three types of content: text, graphics, and raster-based images. Graphics may be further divided into vector-based and raster-based graphics. Vector-based graphics may be similar to text, being mainly line drawings. Raster-based graphics may be similar to
10 images, with most or all pixels filled by colors. Therefore, vector-based graphics may be treated as text, and raster-based graphics may be treated as a raster-based image. Color hue shift artifacts may be most severe for large size images, and less pronounced or absent from small imagerettes. An exemplary printhead may have a width of one inch, so an image that is small (less than about one to
15 two inches) may have a color hue shift that is not noticeable. Accordingly, larger size images may be identified according to their data content and printed selectively with a uni-directional mode to suppress the color hue shift artifact. Other print content may be printed more rapidly with a bi-directional mode without substantial degradation of print quality.

20 Content analysis may be performed by counting all non-white pixels in each raster row or print data corresponding to a page of printed output. Such an analysis may be termed a horizontal projection of the print data and may be performed preferably on contone pixels rather than halftone pixels. Since only non-white pixels are counted, the same algorithm may be used for a black and
25 white image and a color image. These horizontal projections may be plotted relative to the row number (the X-axis) and rotated ninety degrees counterclockwise relative to the graphs show in Figs. 6, 8, and 10. With print data defining a page of text, the horizontal projection of raster rows (parallel to the printhead scan axis) may be generally characterized by peaks and valleys. A
30 larger image, with few non-white pixels, may be characterized by an elevated plateau(s) or peak(s) with few or no valleys.

Each horizontal projection may be compared with a set of two thresholds related to width (content of each row) and height (number of contiguous rows) of the raster rows. For example, in an exemplary embodiment, the two thresholds may be a width threshold of sixty, corresponding to 60% of the width of the printed region of the page, and a height threshold of one-hundred, corresponding to one-hundred raster rows. Accordingly, in this example, an image should have a content (size) corresponding to at least 60% of the page width in non-white pixel content and one-hundred rows in height at this non-white content, to be printed uni-directionally.

In some embodiments, content analysis may be performed to select the number of passes with which to form each type of printed output. For example, text, vector graphics, and imageres may be printed with one-pass printing and larger raster-based images may be printed with multiple-pass printing. Multiple-pass printing, as used herein, places colorant on overlapping regions of a print medium during multiples passes of a printhead over the overlapping regions. Single- or one-pass printing places colorant on nonoverlapping regions of a print medium.

It is believed that the disclosure set forth above encompasses multiple distinct embodiments of the invention. While each of these embodiments has been disclosed in specific form, the specific embodiments thereof as disclosed and illustrated herein are not to be considered in a limiting sense as numerous variations are possible. The subject matter of this disclosure thus includes all novel and non-obvious combinations and subcombinations of the various elements, features, functions and/or properties disclosed herein. Similarly, where the claims recite "a" or "a first" element or the equivalent thereof, such claims should be understood to include incorporation of one or more such elements, neither requiring nor excluding two or more such elements.